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TECHNICAL DISCUSSION

During the period covered by this report work has been accomplished in the following areas:

NONLINEAR PROBLEMS

An analysis was made of the non-linear oscillations of a fluttering plate employing von Karman's large deflection equations and quasi-steady aerodynamic theory¹. A Galerkin procedure was used which led to a system of non-linear differential-equations. These were solved by numerical integration. (The above work was actually accomplished before the grant was begun but after the proposal was submitted. It is included here along with five (5) reprints of the journal article¹ for the sake of completeness). The use of quasi-steady aerodynamic theory limits the range of Mach number for which the above analysis is useful. Therefore subsequent work has considered the full linear potential aerodynamic theory accounting for the three-dimensionality of the flow and the memory of the fluid. A paper² has been submitted for publication (a copy is enclosed) which describes the calculation of the aerodynamic forces using Fourier and Laplace transform techniques. These aerodynamic forces have been employed to again determine the non-linear oscillations of a fluttering plate. The analysis now leads to a system of non-linear integral-differential equations because of the dependence of the aerodynamic forces on the past history of the plate motion. A copy of a preliminary draft paper discussing this work is enclosed³.

An ongoing effort is a Ph.D. thesis study which considers comparisons between the above theoretical results and experimental results available in the literature. Based on such comparisons refinements in the mathematical model are being made. Also improvements in solution techniques are being accomplished.

In future work it is recommended that the work be extended to include:

- (i) plates of large length/width ratio
- (ii) cylindrical and shallow shells
- (iii) effects of viscosity in the fluid model
- (iv) the effect of external forces such as the fluctuating pressures in a turbulent boundary layer.

MATHEMATICAL METHODS FOR LINEAR INTEGRAL-DIFFERENTIAL EQUATIONS

An investigation of the use of transform methods for this class of problems has demonstrated that, though feasible, they are not the most advantageous. The primary difficulty is the determination of an appropriate integration contour for the transform inversion. In considering alternative procedures, it has been found that another approach is more advantageous in terms of computational simplicity and economy as well as flexibility in treating a more general class of problems. This procedure is the so-called "initial value approach to boundary value problems"⁴. The basis of the method is the superposition of solutions of certain related initial value problems to satisfy the boundary conditions of the boundary value problem. This technique has been used to reproduce known results previously obtained by other methods and presently is being exploited to consider:

- (i) two-dimensional plate with linear potential aerodynamic theory
- (ii) plates of variable stiffness and mass properties
- (iii) plates of large length/width ratio

For (ii) and (iii) the conventional solution techniques, e.g. Galerkin's method, are ill-suited.

The principal limitation of this method (as with the transform methods) is that it is only applicable to linear problems.

An interesting by-product of this approach has been the discovery of new analytical results for so-called multibay panels, i.e. panels on multiple supports⁵. A copy of a note describing these results is enclosed.

BUDGETARY DISCUSSION

A portion of the funds originally earmarked for publications and travel, approximately \$500.00, has been used instead to support a research assistant over the summer.

REFERENCES

1. Dowell, E.H.: Nonlinear Oscillations of a Fluttering Plate. AIAA Journal, 4, 1267-1275 (July 1966).
2. Dowell, E.H.: Generalized Aerodynamic Forces on an Flexible Plate Undergoing Transient Motion. To be published.
3. Dowell, E.H.: Nonlinear Oscillations of a Fluttering Plate II. To be published.
4. Fox, L.: The Numerical Solution of Two-point Boundary Problems in Ordinary Differential Equations. Oxford, Clarendon Press, 1957.
5. Dowell, E.H.: On the Flutter of Multibay Panels at Low Supersonic Speeds. To be published.